521282S Biosignal processing II (Lab exercises, spring 2019)

Lab – II EEG-based depth of anesthesia measurement

Objective

The aim of this exercise is to use spectral analysis of EEG for the estimation of depth of anesthesia. A sample of EEG data recorded from one frontal channel during induction of anesthesia with propofol is used. In the beginning of the recording, the patient is awake. A fixed propofol infusion rate was used so the anesthesia deepens continuously and, in the end of the recording, burst suppression pattern (very deep anesthesia) is reached.

In the exercise, first, four bandpass filters are designed to extract delta, theta, alpha, and beta activities from the raw (artifact-free) EEG. The envelopes of the bandpass filtered signals are estimated with a root-mean-square (rms) algorithm. Next, the spectrogram of the signal is calculated and the relative powers in delta, theta, alpha and beta bands are estimated from it. Finally, using the spectrogram, spectral entropy is calculated for the EEG.

In order to pass the exercise, all correctly executed task results marked with an arrow bullet (➢) must be personally presented to a course assistant during the scheduled laboratory exercise.

Implementation

The data and instructions needed for this exercise can be found in the Biosignal Processing II course webpage (see the Noppa system link in the footer of this document).

Download the data file '521282S_data_2.mat' containing the EEG data vector variable 'signal', time vector 't' (time in minutes), and sampling frequency 'Fs'. Familiarize yourself with the functions 'envelope' and 'spectrogram' which are needed in this exercise. Also, recall the usage of 'fdatool' which was utilized in the laboratory work 1.

Store your solutions in **a single script code m-file** that provides the required task results.

1. Raw EEG and activities in different bands

Load the data file '521282S_data_2.mat'. Launch the filter design tool by command 'fdatool'. Design four bandpass filters for the extraction of delta (1-4Hz), theta (4-8Hz), alpha (8-12Hz), and beta (12-25Hz) activity. Export the codes to files (File→Generate MATLAB Code→Filter Design Function), and by copying the exported code, add the filters to your working script. Use the following parameters when creating the filters:

- Response Type: Bandpass, Design Method: FIR (Window), Filter Order: 800, Options: Scale Passband=Yes; Window=Hamming, Frequency Specifications: Fs=200Hz. For Fc1 and Fc2, use the frequency limits given above for different activities.

Filter the raw EEG using the four created filters and 'filter' function. Calculate the rms envelopes of the raw EEG as well as the filtered signals using 'envelope' function and a window size of 30s.

- ➢ Plot the raw EEG and the four filtered signals (delta, theta, alpha, and beta activity) utilizing the time vector 't'. Plot all of the signals in the same figure but use different axes. For this, utilize the function 'subplot' with five rows and one column.
- ➢ To better visualize the changes in the activities, plot the upper and lower envelopes on all of the signals. Use the command 'hold on' to keep the earlier data when plotting new to the same axis. Plot the envelopes using red color to make them clearly visible. Scale all of the axes using command 'set(gca,'ylim',[-0.03 0.03])' for easier comparison.

2. Spectrogram and relative powers

Calculate the spectrogram of the signal using the function 'spectrogram'. For input, use the raw EEG data, 30s window, 29s overlap, and sampling frequency 'Fs'. In addition, define the frequencies at which the spectrogram is computed (input parameter 'F' given before the sampling frequency 'Fs') by vector [0.1:0.1:32] to get the estimates between frequencies 0.1Hz and 32Hz with 0.1Hz resolution. Collect all of the four output parameters ('S', 'F', 'T', and 'P') of the function.

Calculate the relative powers in delta, theta, alpha, and beta bands by summing the power spectral density values ('P') in the corresponding frequencies at each time point and dividing the sum by the power in the entire frequency range (0.1-32Hz) at the same time point. You can use output variable 'F' to confirm the samples corresponding to the frequency bands.

- ➢ Plot the power spectral density estimates as a function of time by command 'imagesc(T/60,F,log10(P),[-7 -3])'. Use command 'axis xy' to reflect the image vertically. To leave space for the future results in the same figure, use the function 'subplot' with three rows and one column and make the plot to the first axis.
- ➢ Plot all of the relative powers in the second axis of the same figure. Again, use 'hold on' command to keep the earlier data when plotting new to the same axis. As with the power spectral densities, utilize time variable 'T' for plotting (transform to minutes). Use different colors to make the comparison of different relative powers possible. Scale the y axis between 0 and 1. Use function 'legend' to show which data is presented in the axis.

3. Spectral entropy

Utilizing the power spectral density estimates ('P'), calculate the spectral entropy (SE) for the EEG as a function of time:

$$\mathrm{SE} = \frac{-\sum_{i=f_l}^{f_h} P_n(i) \log P_n(i)}{\log N_f}.$$

For the calculation, use the entire frequency range (f_l = 0.1Hz, f_h = 32Hz) and base 2 logarithm (function 'log2'). N_f is the number of frequency bins. Perform the calculation in a for-loop going through all of the time points one by one. Before applying the equation, normalize the power spectrum to have a sum of 1:

$$\sum_{i=f_l}^{f_h} P_n(i) = 1.$$

- Plot the spectral entropy in the same figure with the power spectral density estimates and relative powers (third axis). Again, utilize time variable 'T' for plotting.

The material used in this exercise can be found in the course web page at
https://noppa.oulu.fi/noppa/kurssi/521282s/harjoitukset